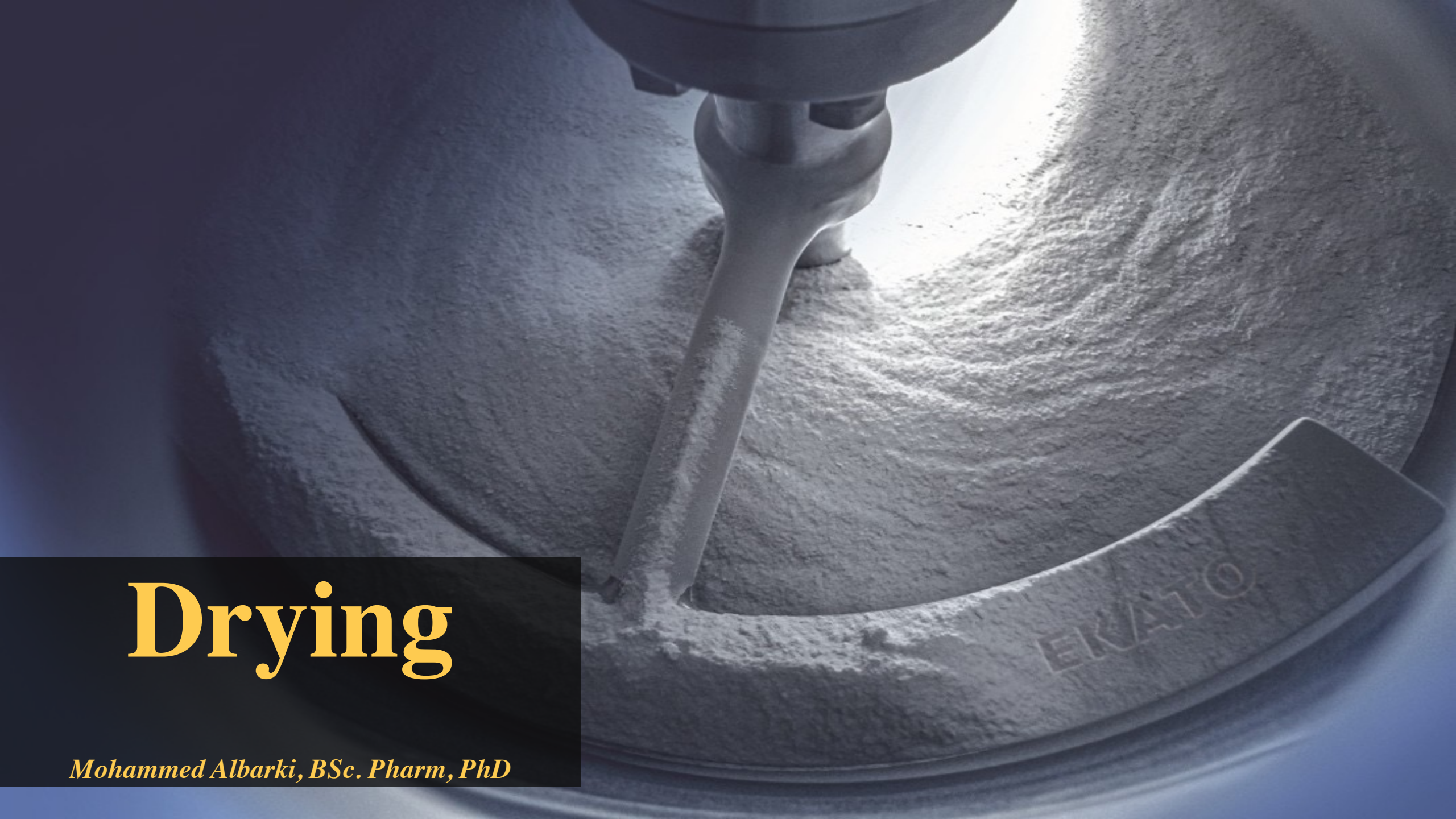


Drying

Mohammed Albarki, BSc. Pharm, PhD

Types of Dryers

- When considering how to dry material, certain points should be considered:

1. **Heat sensitivity** of the material being dried
2. **Nature of the liquid** to be removed.
3. The **quantity** of product to be dried (scale of operation).
4. **Physical nature** of the material.

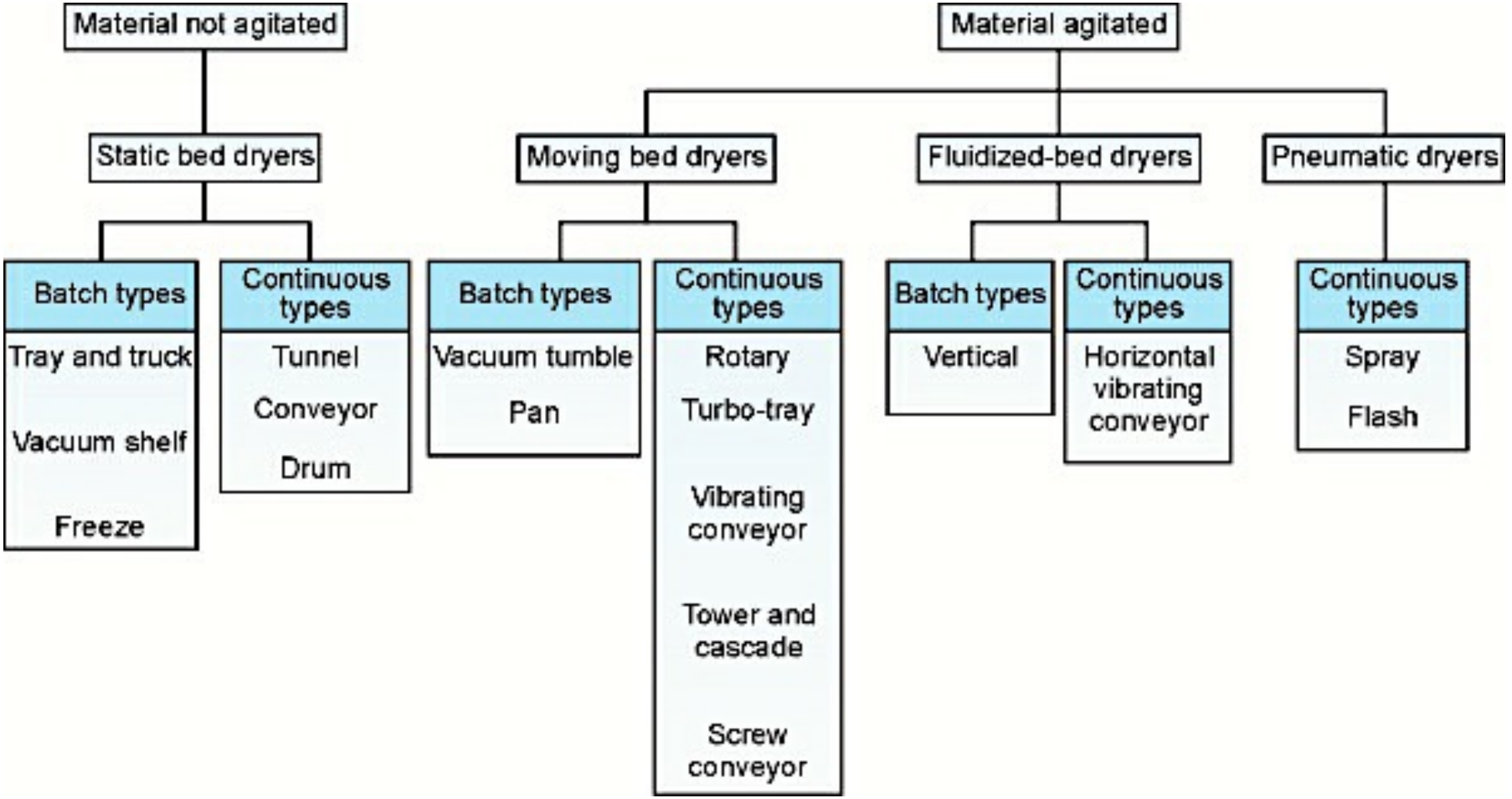
- Dryers can be classified based on the **method of heat transfer** or **method of sample handling.**
- In the **first** classification **dryer design and energy requirement** are important while in the **second** attention is given to the **type of the substance to be dried**.

Types of Dryer

- Classification by the method of **sample handling:**
- Two main classes under this classification: presence or absence of agitation of the material to be dried.
  - Agitation dryers are not recommended for friable materials
- Based on this classification there are 4 classes of dryers:

1. **Static bed dryer**
2. **Moving bed dryer**
3. **Fluidized bed dryer**
4. **Pneumatic dryer**

Classification of The Dryers



Static Bed Dryers: 1- Tray Dryer

- **The tray dryer** consists of a cabinet shelf or compartment in which the material to be dried is spread on trays.
- There is **no particle movement**; sometimes only movement of the entire drying mass.
- The exposed surface can be **increased by decreasing** the thickness of the bed.
- **Advantages**:

1. **Versatile** in arrangement and design.
2. Relatively **low cost**.

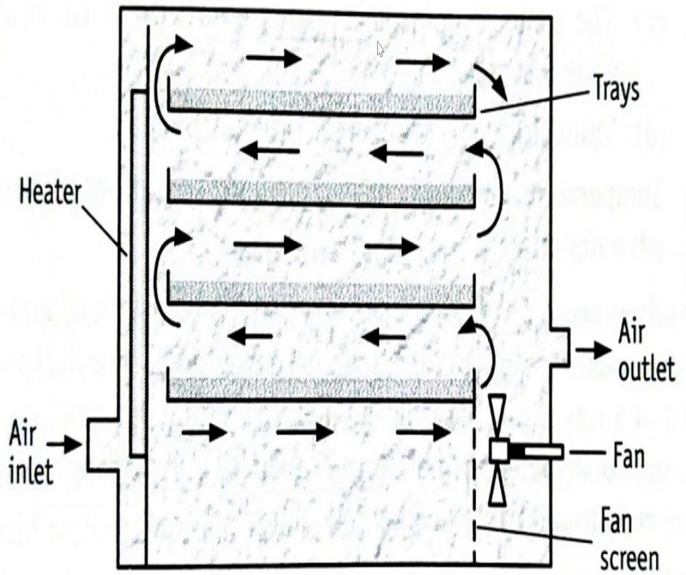
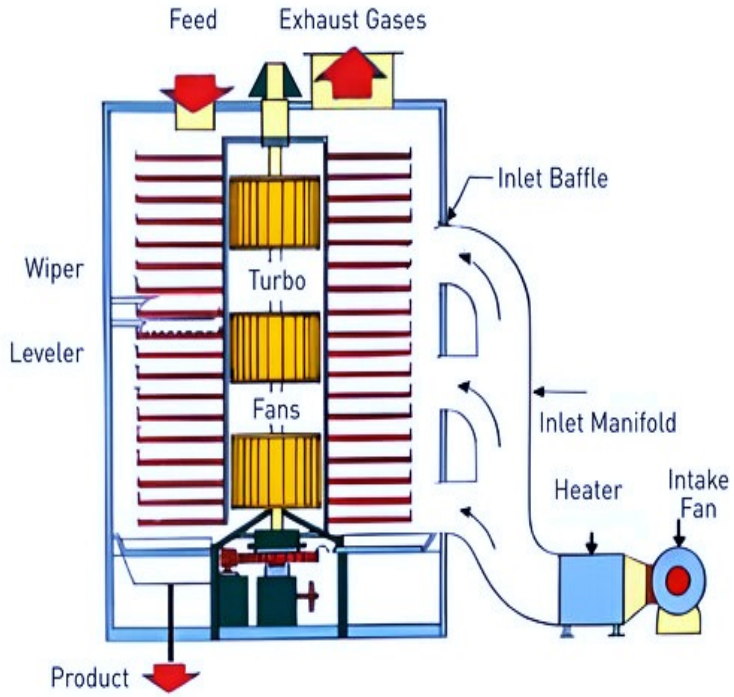


Figure 8-5. Tray dryer.

Moving Bed Dryer

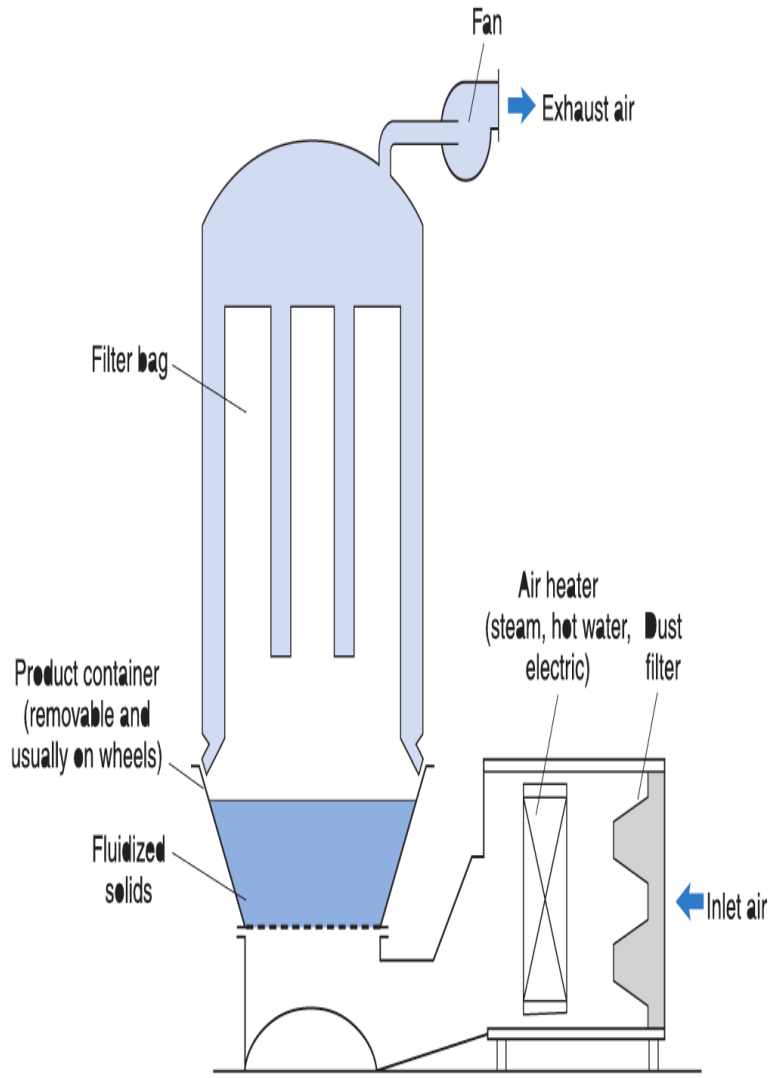
- **Turbo-Tray Dryers**
- This type is a **continuous shelf**, moving-bed dryer.
- It **consists of** a series of rotating annular trays arranged in a vertical stack. Rotating **slowly** at 0.1 to 1.0 rpm.
- **Heated air** is circulated by turbo-type fans mounted in the stack center.
- Wet mass fed through the roof of the dryer is leveled by a stationary wiper.
- Then the dried material is **pushed through radial slots** onto the tray below.
- After each cycle, the mass transfers to the next shelf until discharge at the bottom.
- The **drying rate** is faster than the tunnel dryer due to the continuous exposure to the air.



https://youtu.be/-XpohB2hUoM

Fluidized Bed Dryer (FBD)

- The solids are partially suspended in the gas stream (the mixture behaves like a liquid) and the solid is fluidized.
- The fluidization technique is **used for** drying granular solids, as each particle is surrounded by the drying gas.
- The intense mixing results in uniform conditions of **temperature, composition, and particle size distribution throughout the bed.**
- The resultant granules are not wet nor completely dried to avoid cracking.

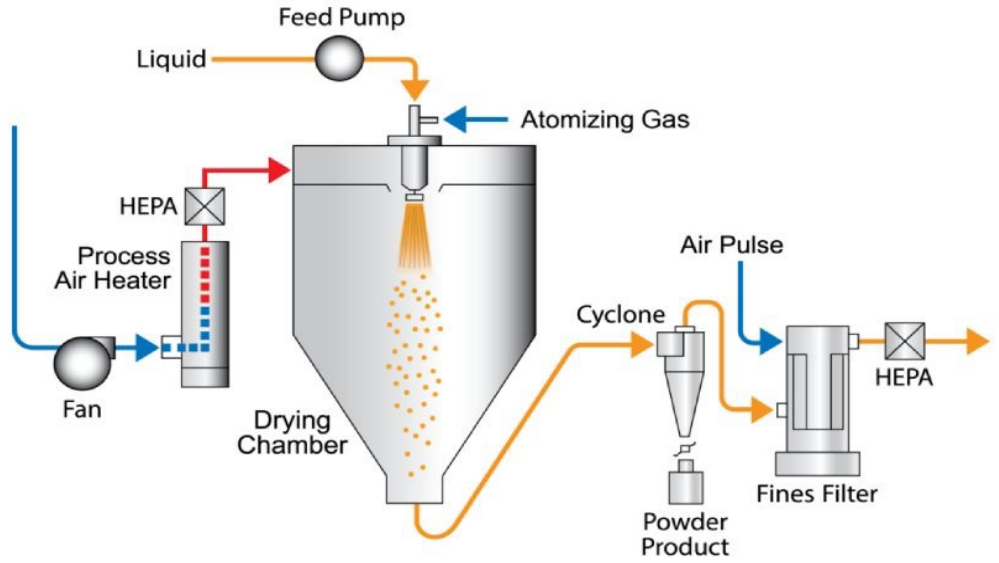


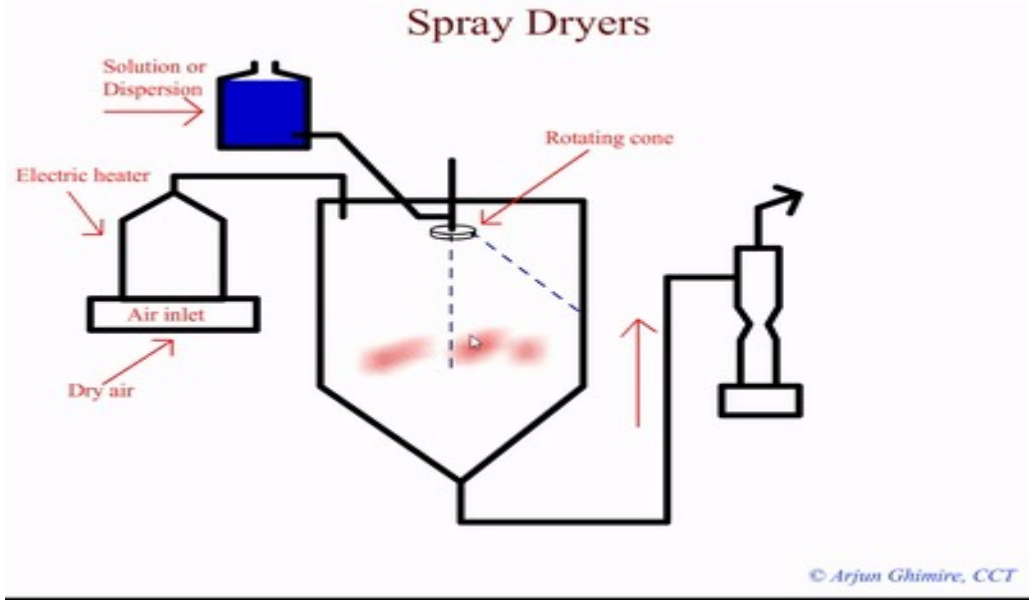
Advantaged of FBD

1. **Efficient heat and mass transfer** give high drying rates, so drying **times are short**.
    - Apart from obvious economic advantages, the heat challenge to thermolabile materials is **minimized**.
2. The fluidized state of the bed ensures that **drying occurs from the surface of all the individual particles**. Hence, most of the drying will occur at a **constant rate**.
3. **The turbulence** in a fluidized bed causes **some attrition** to the surface of the granule. This produces a more **spherical free-flowing product** which will reduce the problem of aggregation and migration of color.

Pneumatic Dryer

- **Spray Dryer**
- It can handle **only fluid materials** such as solutions, slurries, and thin pastes.
- Feeding of fine droplets of fluid into the hot gas stream.
- The dried powder is carried by the **gas current and gravity flow** to the collection system.

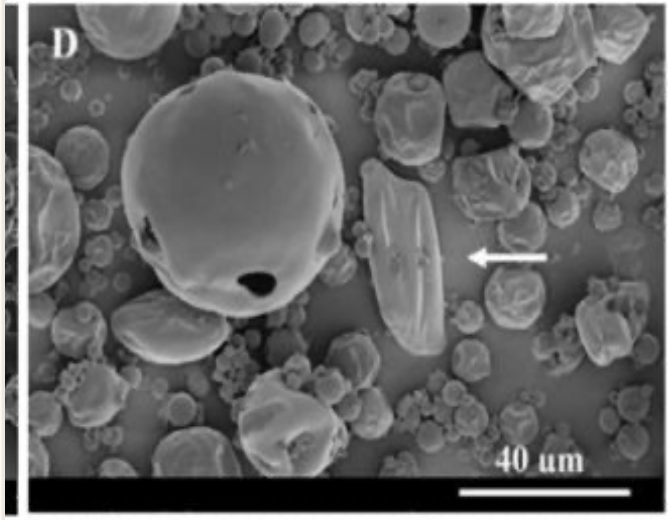


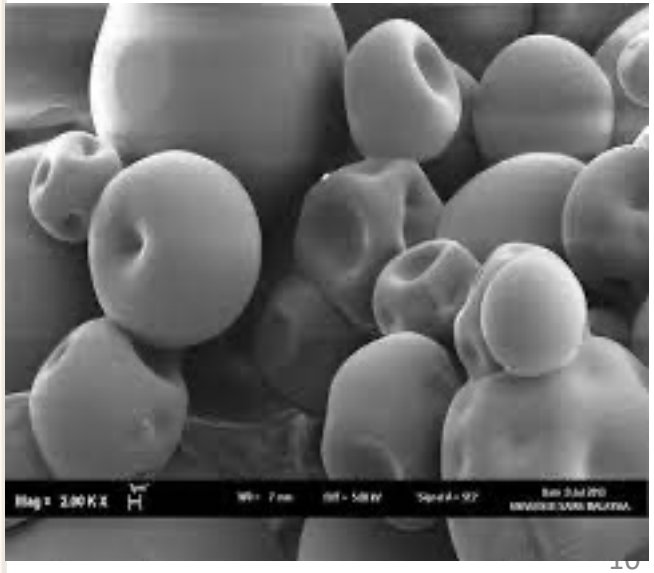


Principle

1. When the **liquid droplets** come into contact with the **hot gas**, they quickly reach a high temperature and the water at the **surface will evaporate** and form a tough shell solid.
2. The **diffusion rate** of the liquid is slower than heat transfer. → The **internal pressure** causes the droplet **to swell**, and the **shell becomes thinner**, allowing **faster diffusion**.
3. **If** the shell is nonelastic or impermeable, it ruptures, producing either fragments or bud-like forms.

- Thus, spray-dried material consists of intact spheres, spheres with buds, ruptured hollow spheres, or sphere fragments





Spray Drying and Spray Congealing

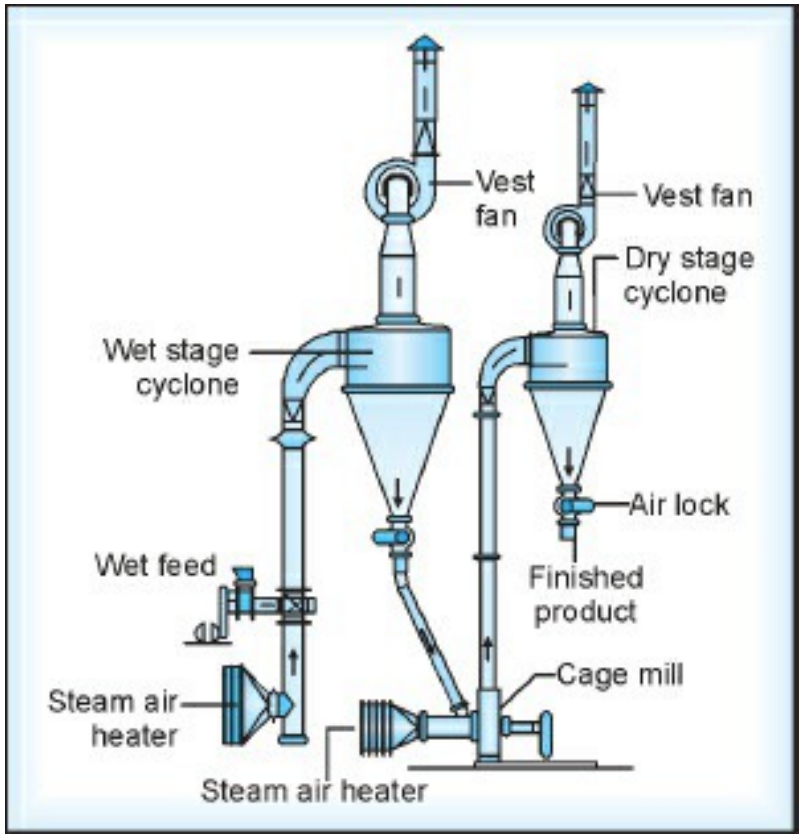
- Spray drying is rapid drying and a unique form of the product.
- There are three major uses:
  1. Drying **heat-sensitive** materials,
  2. Changing the physical form of materials (in tablet and capsule manufacture)
  3. Encapsulating solid and liquid particles
- Spray drying is used in tablet and capsule formulations.
- The drying process changes the shape, size, and bulk density of the product.
- The spherical particles **flow better** than the same product dried by the conventional method **due to** size and shape uniformity.

Spray Drying and Spray Congealing

- **Spray Congealing:**
- Spray drying is used in the coating and encapsulation of both solids and liquids.
- Chilling spray (congealing) consists of suspending the particles in a **molten coating material** and pumping the slurry into a spray dryer in which **cold air** is circulated.
- Spray congealed coatings are **used mainly for 1) taste masking** and 2) **sustained-release** formulations.

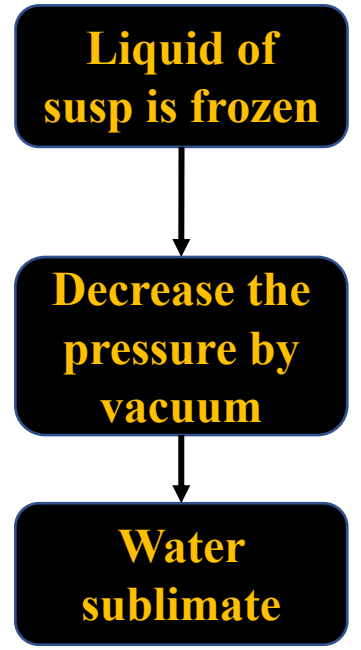
Flash Dryer

- The moistened solid is suspended in a finely divided state [**velocity (3000-6000** feet/min)] at [**temperature (300-1300**◦F] air stream
- The flash drying is a **short-time process**. This is why it is called a flash dryer.



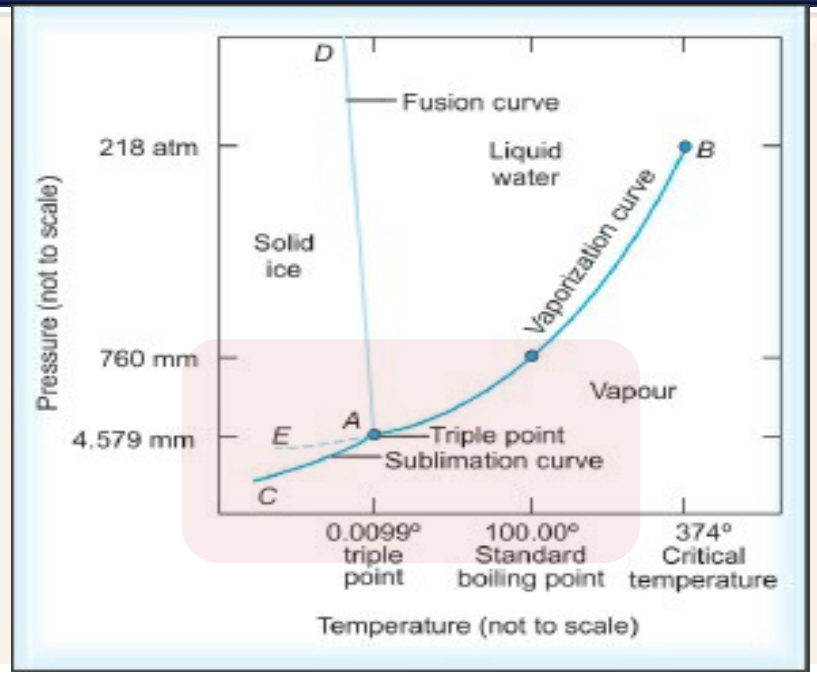
Specialized Drying Methods

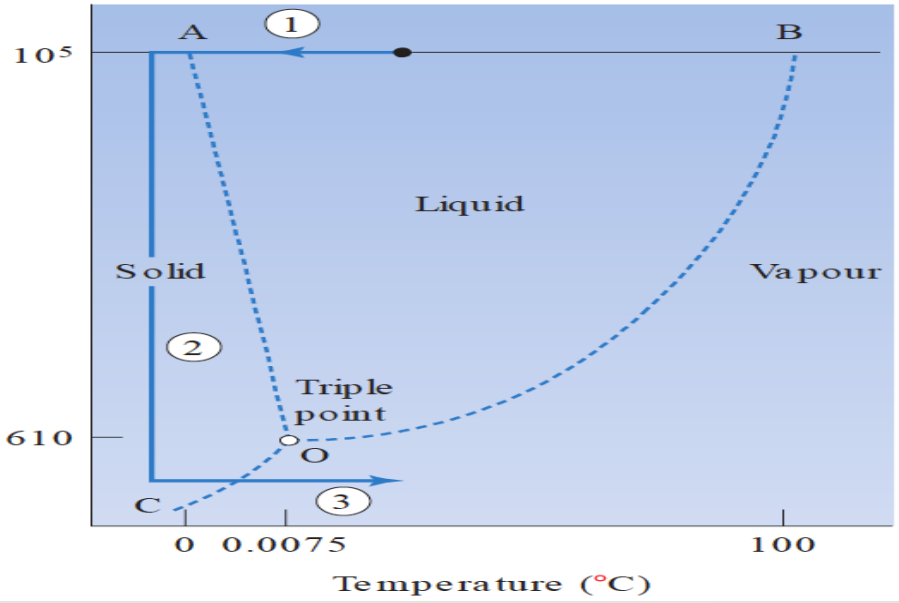
- **Freeze Drying**
- The process is also called **lyophilization, and sublimation**.
- The drying of **heat-sensitive materials** must be dehydrated to a solid state **to maintain the stability** through frozen then under a high vacuum to heat (by conduction or radiation) to sublime the frozen liquid leaving only the solid.
- Examples; blood serum, plasma, antibiotics, hormones, bacterial cultures, vaccines, and food.
- The dried product is called **lyophilized** and can be redissolved (or re-suspended) by adding water before its use by a process called **reconstitution**.
- In freeze-drying the water **passes directly** from the solid state (ice) to the vapor state without passing through the liquid state. As shown in the schematic pressure-temperature diagram for water.



Freeze Drying

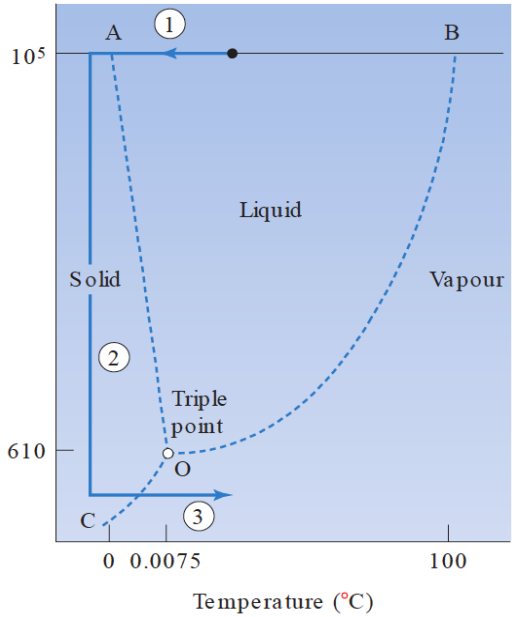
- The theory and practice of freeze drying are based on an understanding and application of the **phase diagram** for the water system.
- Sublimation occurs at pressure and temperature below that for the triple point (4.579 mm Hg, and 0.0099 ˚C)



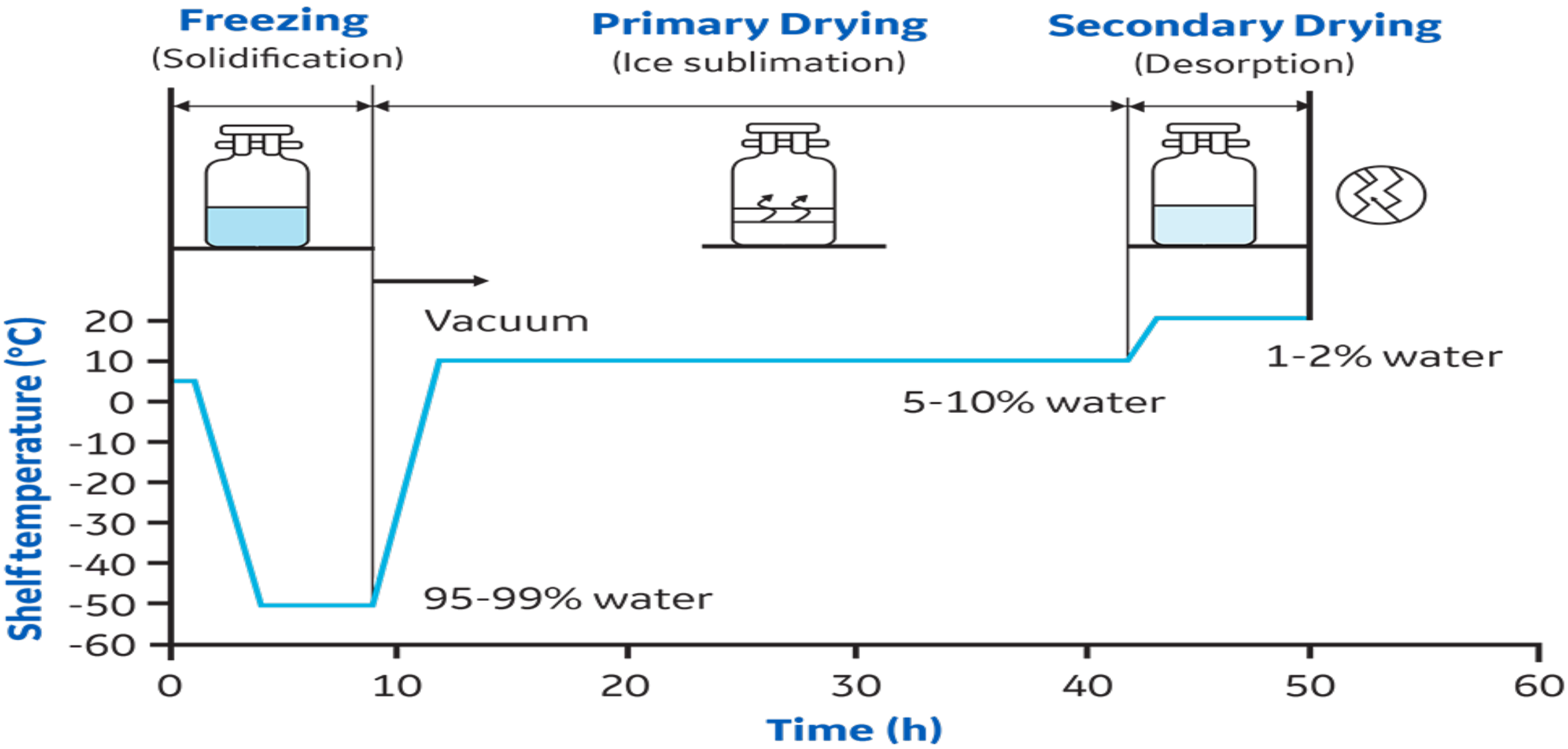


Stages of Freeze Drying

1. **Pre-freezing:** The material is frozen by keeping the material below or at −20◦C (freezing before vacuum to prevent foaming).
2. **Vacuum: Reducing the atmospheric pressure** to below that of the triple point of the product
   - Rotary pumps on a small scale and ejector pumps on a large scale are used to reduce the pressure sufficiently.
3. **Primary Drying:** latent heat of sublimation must be provided and the vapor removed. Primary drying by sublimation can remove the **unbound water.**
   - This stage will result in a **powder with very low moisture** content.
4. **Secondary Drying**: It is used to remove bound water or traces of water left after primary drying.
   - The temperature is raised (up to 50˚C) or desiccant is used to carry secondary drying.

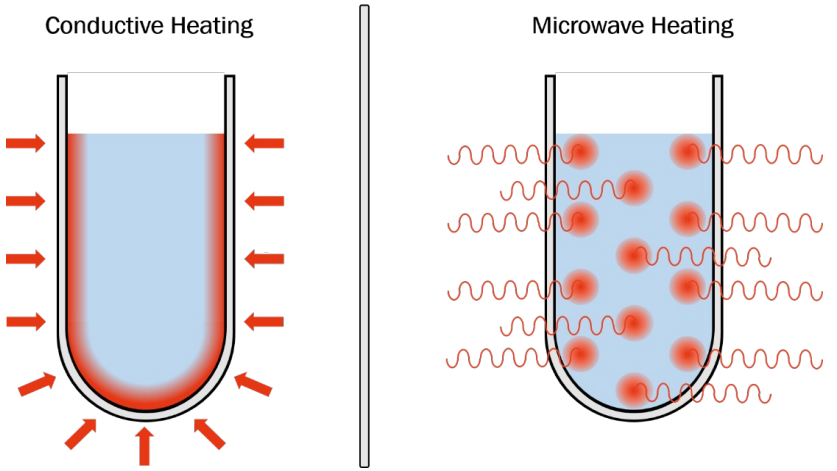


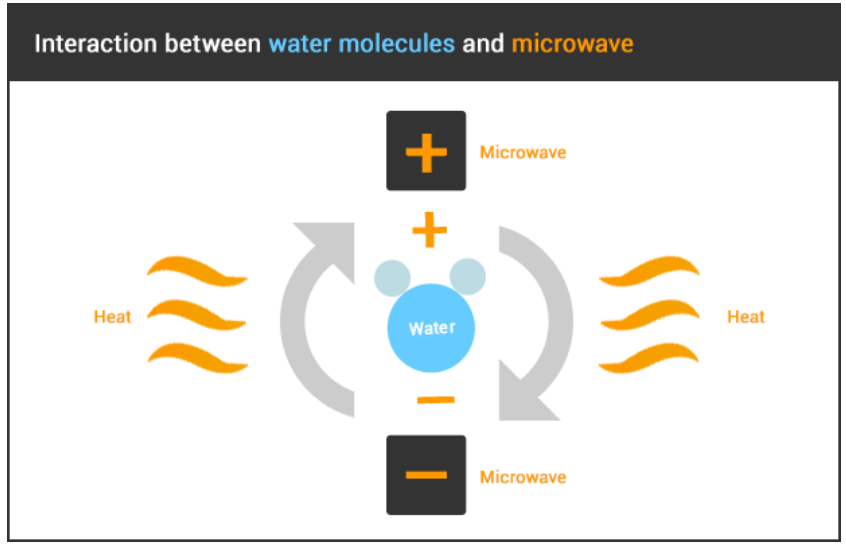
Lyophilization Process



Specialized Drying Methods

- **Radiation heat transfer**:
- Heat "transmission" by radiation differs from heat transfer by conduction or convection in that **no transfer medium** (solid, liquid, or gaseous) needs to be present.





Microwave Radiation

- The application of microwave energy to the drying of solids represents a radical departure from conventional means of drying.
- Instead of **applying heat externally to a material**, energy in the form of microwaves **is converted** into internal heat by interaction with the material itself.
- This permits **extremely rapid heat** transfer throughout the material leading to rapid drying.
- The moisture is **mobilized as a vapor** rather than a liquid, and its movement to the surface can be extremely rapid because it **does not depend** on mass concentration gradients or on a **slow** liquid diffusion rate.